

Electro-Optical System Simulation and Performance Prediction Extensions to EODES

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LONG-TERM GOALS

The EODES suite of electro-optical system models is designed to provide a high-fidelity simulation capability and reliable performance prediction tools. EODES simulations are used to analyze the performance of existing electro-optical identification (EOID) systems and to inform new system design concepts. Performance prediction tools have been incorporated into tactical decision aids at the Naval Oceanographic Office, which provide near real-time performance assessments for available EOID assets to assist mine countermeasures (MCM) commanders and mission planners in formulating effective tactics. The long-term goal of the EODES project is to develop a complete set of validated models for underwater and airborne electro-optical systems and extend the simulation and performance prediction capabilities to all relevant Navy systems. EODES models are currently being certified and placed under configuration management as part of the Oceanographic and Atmospheric Master Library (OAML) administered by the Commander of the Naval Meteorological and Oceanographic Command (CNMOC).

OBJECTIVES

EODES image transfer modeling is based on physical models of radiative transfer in turbid media under the assumption of small-angle scattering, while various scanning techniques are modeled using Fourier optics [1]. A key objective of this project is to develop flexible and efficient numerical methods to solve these physical models and provide high-fidelity simulation and performance analysis for electro-optical imaging sensors. The physical and systems models already incorporated within EODES have undergone a rigorous validation process [7,8] and continuous validation remains a key objective. The aim is to provide modeling and simulation capabilities that are relevant to the Navy, whether in the engineering design phase of next-generation EOID sensors or for tactical performance prediction as part of today's MCM operations. System models, as they are developed, will be submitted to the Oceanographic and Atmospheric Master Library (OAML) Software Review Board (SRB) for certification as Navy standard models. Performance prediction models are expected to be transitioned to the Naval Oceanographic Office (NAVOCEANO) upon receiving OAML certification.

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APPROACH

EODES implements high-fidelity mathematical models for radiative transfer and image scanning. Simulation and performance prediction tools address a wide variety of electro-optical sensor types, provide for detailed specification of the system design and environmental conditions, and have been rigorously validated against field test and laboratory data. EODES software is computationally efficient and portable across various computer platforms. EODES products are used to analyze engineering design tradeoffs, inform investment and procurement decisions, and to provide tactically relevant system performance estimates.

WORK COMPLETED

Metron continued its analysis of a new co-located, pulsed scanning system that is being developed by teams from Scripps Institution of Oceanography (POC: Jules Jaffe) and Lockheed Martin Aculight Corporation (POC: Dan Templeman). In particular, Metron modeled the impact of laser pulse-to-pulse instability and the potential benefit of image postprocessing techniques used to reduce this source of noise. Metron also evaluated the temporal response characteristics of the receiver and the potential need for a narrow-band filter to mitigate solar light pollution. The latter analysis involved detailed models for light propagation across the entire visible spectrum and the receiver spectral sensitivity profile. Models developed as part of this effort are being added to EODES to provide a simulation capability for the SIO/LMA system (see Fig. 1)

Metron performed a preliminary validation of the Streak Tube Imaging Lidar (STIL) model using data from an August 2001 field test of electro-optical imaging sensors sponsored by ONR. The comprehensive data set obtained during the tests included STIL imagery for various military targets, technical panels, and clutter objects. Trials were performed under a range of environmental conditions and at various heights above the ocean floor. Measurements of the depth-dependent optical properties of the water column were also taken during tests. Metron used the image data, environmental measurements, and test specifications to evaluate EODES simulation and performance prediction models of the STIL sensor.

The EODES performance prediction model for the AQS-24 electro-optical identification (EOID) system was submitted to the Oceanographic and Atmospheric Master Library (OAML) Software Review Board (SRB) for certification as a Navy standard model. The model has been recommended for approval by the CNMOC Independent Model Review Panel (CIMPREP), and a final report has been submitted to the OAML Software Review Board (SRB). The review process required a continuous interaction with the CIMREP to clarify technical points, answer questions, and provide additional supporting data. Several studies were conducted to explain model results and ensure that they comported with observed imaging phenomena (see, for example, the analysis contained in Ref. [11]).

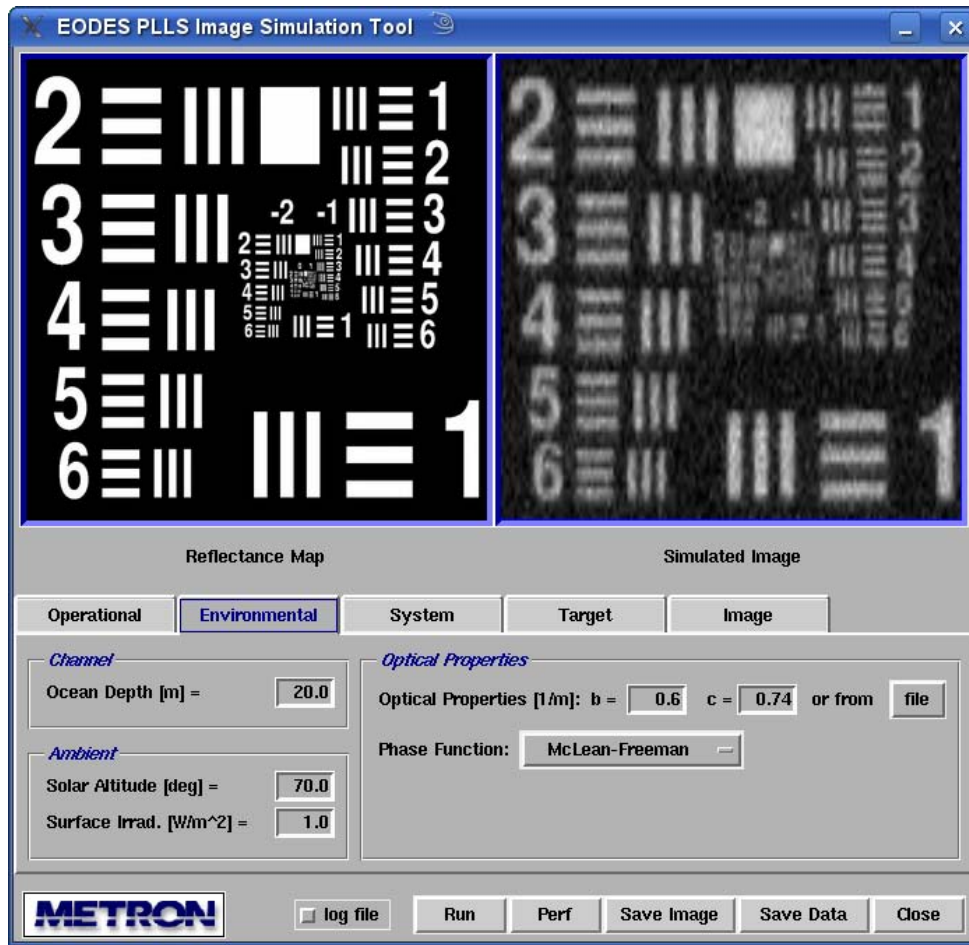


Figure 1: Graphical user interface for the EODES pulsed laser line scan (PLLS) simulation tool, which has been enhanced to model a new sensor being developed by Scripps Institute of Oceanography and Lockheed Martin Aculight Corporation.

RESULTS

Modeling and analysis of an electro-optical imaging system being developed by Scripps Oceanographic Institution (SIO) and Lockheed Martin Aculight (LMA) showed that the pulse-to-pulse instability ($\leq 5\%$) of the laser source did not significantly impact electro-optical identification (EOID) performance as quantified by the signal-to-noise ratio (SNR). Another analytical investigation concluded that a narrowband filter in front of the receiver optics would significantly improve performance in typical situations. It was also determined that the long fall time (see Fig. 2) of the proposed photodetector did adversely impact image quality. These results informed design decisions that must weigh imaging performance against the processing requirements and the size and power constraints of the sensor.

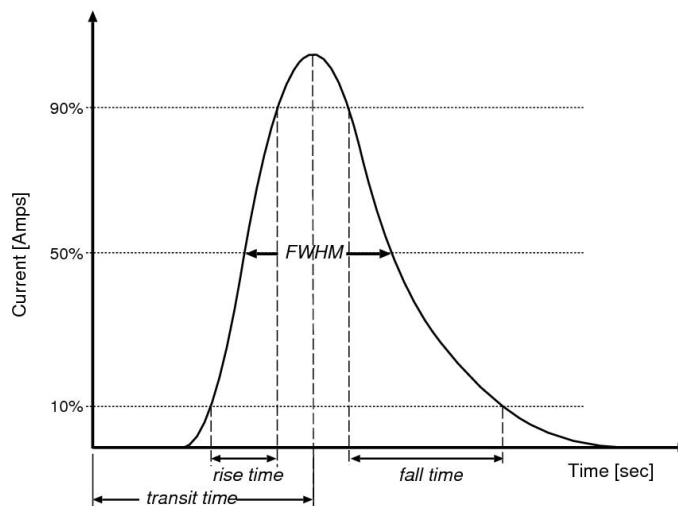


Figure 2: Characteristics of a detector pulse waveform due to a photon impacting the photocathode.

Additions to EODES, including pulse-to-pulse laser source instability, provide a user-friendly simulation tool for the SIO/LMA system (see Fig. 1), which is a variant of the pulsed laser line scan (PLLS) sensor. A performance prediction model [3,4] has been modified to obtain image quality predictions for the SIO/LMA system, which will be validated once test data becomes available. Other additions to the EODES modeling suite include the Fournier-Forand and exponential phase functions and improvements to the ambient solar light model.

Results of the preliminary validation study for the Streak Tube Imaging Lidar (STIL) sensor showed good agreement between EODES simulations and actual sensor imagery. In addition, the image quality predicted by EODES models was in good agreement with that obtained by the sensor during field testing. Additional validation requires controlled laboratory data, which we hope to obtain in FY11.

The Oceanographic and Atmospheric Master Library (OAML) certification process is nearing completion, with a final report from the CIMREP completed and scheduled to be presented to the OAML Software Review Board (SRB). EODES has been recommended for approval by the CIMREP panel, made up of ocean optics experts from NRL-Stennis and NAVOCEANO. Upon formal certification the EODES performance prediction models will be the first electro-optical model included in the OAML.

IMPACT/APPLICATIONS

EODES simulation and performance prediction software was developed for the purpose of analyzing existing and prospective electro-optical systems and to provide EOIDS system performance estimates to inform tactical decisions for MCM operations. EODES models are currently being used to examine the performance of several underwater systems for the ONR and are being incorporated into tactical decision aids at NAVOCEANO.

TRANSITIONS

EODES performance prediction software is expected to transition to the NAVOCEANO upon certification by the OAML SRB.

RELATED PROJECTS

This project is a continuation of a previous effort to develop “A Comprehensive Model for Performance Prediction of Electro-Optical Systems” (ONR contract number N00014-06-C-0070). Another related project was concerned with the demonstration of EODES performance prediction capabilities at the RIMPAC-08 Navy exercise and the submission of EODES software for possible inclusion in the Oceanographic and Atmospheric Master Library (ONR contract number N00014-08-M-0007).

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